INDOOR AIR QUALITY ASSESSMENT

Manchester Memorial Elementary School Annex
43 Lincoln Street
Manchester-by-the-Sea, Massachusetts

Prepared by:
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Center for Environmental Health
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September 2004

Background/Introduction

At the request of Roger Young, Business Manager, Manchester Essex Regional School District, the Massachusetts Department of Public Health (MDPH), Center for Environmental Health's (CEH), Bureau of Environmental Health Assessment (BEHA), was asked to provide assistance and consultation regarding indoor air quality at the Manchester Memorial Elementary School (MMES), 43 Lincoln Street, Manchester-by-the-Sea, Massachusetts. On March 7, 2004, a visit was made to this school by Michael Feeney, Director of Emergency Response/Indoor Air Quality (ER/IAQ), BEHA, to conduct an indoor air quality assessment. Mr. Feeney was accompanied by Sharon Lee, Environmental Analyst, ER/IAQ during the assessment. Reports of inadequate ventilation, odors, lack of temperature control and other indoor air quality concerns prompted the assessment.

The MMES consists of two separate buildings: the main building and the library or annex. The annex is a one room, single story structure built in 1953. The annex contains a main library room and restroom. Windows are openable along the south wall, which consists of single-paned glass. The roof is peaked and covered with asphalt shingles. Please note that the main MMES building is the subject of a separate report.

Methods

Air tests for carbon monoxide, carbon dioxide, temperature and relative humidity were conducted with the TSI, Q-Trak, IAQ Monitor, Model 8551. Air tests for airborne particle matter with a diameter less than 2.5 micrometers were taken with the TSI, DUSTTRAK™ Aerosol Monitor Model 8520. Screening for total volatile organic compounds (TVOCs) was conducted using a Thermo Environmental Instruments Inc., Model 580 Series Photo Ionization Detector (PID). BEHA staff also performed visual inspection of building materials for water damage and/or microbial growth.

Results

The school complex houses kindergarten through sixth grades with a student population of approximately 400 and a staff of approximately 30. One librarian works in the library, which is visited by a number of students throughout the day. Tests were taken under normal operating conditions and results appear in Table 1.

Discussion

Ventilation

It can be seen from Table 1 that carbon dioxide levels were below 800 parts per million (ppm) in the library, indicating adequate air exchange. However it is important to note that at the time of the assessment only four individuals were present. The ventilation system in the library was deactivated at the time of the assessment. Due to the configuration and condition of the mechanical ventilation systems, carbon dioxide levels in the building would be expected to rise above comfort levels when windows are closed, particularly during winter months and if the room occupancy increased.

Fresh air in library is supplied by a unit ventilator (univent) system (Picture 1). Univents are designed to draw air from outdoors through a fresh air intake located on the exterior wall of the building and return air through an air intake located at the base of each unit (Figure 1). Fresh and return air are mixed, filtered, heated and provided to library through a fresh air diffuser located on the front of the unit. Univents were found deactivated, which prevents a continuous source of outside air to provide ventilation. Obstructions to airflow, such as books and paper on top of the univent fresh air diffusers were also observed. In order for univents to provide fresh air as designed, univent air diffusers and return vents must remain free of obstructions. Importantly, these units must be activated and allowed to operate during school occupancy.

The mechanical exhaust ventilation system in the library consists of a grill installed in a metal ductwork. The metal ductwork is connected to an exhaust vent motor below grade, which directs exhaust air from the building via a subterranean grate (Picture 2). The library exhaust system was not operating during the assessment and the vent was blocked with shelving.

To maximize air exchange, the BEHA recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function (SMACNA, 1994). The date of the last servicing and balancing was not available at the time of the assessment.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix A.

The temperature reading in the library (69° F) was very close to the lower range of BEHA recommended comfort guidelines. The BEHA recommends that indoor air temperatures be maintained in a range of 70° F to 78° F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. In addition, temperature control is often difficult without operating the ventilation systems as designed (e.g., univents/exhaust vents deactivated and obstructed).

The relative humidity measured was 23 percent, which was below the BEHA recommended comfort range. The BEHA recommends a comfort range of 40 to 60 percent for indoor air relative humidity. The sensation of dryness and irritation is common in a low relative humidity environment. Humidity is more difficult to control during the winter heating season. Low relative humidity is a very common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

Water-damaged ceiling tiles (Picture 3) and gypsum wallboard (Picture 4) were observed in the restroom, indicating water penetration or a plumbing leak. Tiles appear to be directly adhered to the ceiling. Replacement of these types of ceiling tiles is difficult, since their removal appears to necessitate the destruction of the tile, which can result in the aerosolization of particulates. Water-damaged ceiling tiles may provide a medium for mold growth and should be replaced after a water leak is discovered and repaired.

The building was originally equipped with a gutter/downspout system, that has since been removed. Areas along the roof soffit have spots of dissimilar/missing paint in an evenly spaced pattern with nail holes, which is likely the location of the gutter brackets (Picture 5). Two pipes in the tarmac that are similar to other downspout drains observed by BEHA staff were seen at the corners of the annex (Picture 6). Without downspouts/ gutters, water accumulates along the exterior walls of the building, subsequently leading to water penetration into the basement crawlspace through the subterranean exhaust vents.

Of note were the east and west wall/roof junctions. It appears that pipe insulation had been inserted into a space that exists between the roof and exterior wall (Picture 7). It is likely that this insulation was installed to prevent cold air penetration. Pieces of solid material were seen below the insulation on bookshelves, which on initial inspection, appeared to be consistent with disintegrating wood. If this insulation was placed to prevent drafts, certain cold weather can create conditions that would cause condensation to accumulate in the junction between hot and cold materials. Condensation is the collection of moisture on a surface that has a temperature below the dew point. The dew point is a temperature that is determined by air temperature and relative humidity. As an example, at a temperature of 70^{o} F and relative humidity of 20 percent, the dew point for water to collect on a surface is approximately 27^{o} F (IICR, 2000). Using actual weather data from January 6 to January 31, 2004, the mean temperature in the Manchester-by-the-Sea area was below 27^{o} F twenty-five of the twenty-six days. Therefore, it was likely that materials at the roof/wall junction were generating condensation during this cold weather, which damaged building materials causing the debris seen on top of bookshelves.

A water bubbler was placed over carpeting (Picture 8). The pressure in the bubbler allows water to shoot over the catch basin and onto the floor. Water spillage or overflow can result in the wetting of the carpet. The US Environmental Protection Agency and the American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24-48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Water-damaged porous materials cannot be adequately cleaned to remove mold growth. The application of a mildewcide to moldy porous materials is not recommended.

Plants were noted in the annex. Plants can be a source of pollen and mold, and can serve as a respiratory irritant for some individuals. Plants should be properly maintained and equipped with drip pans. Plants should also be located away from radiators to prevent the aerosolization of dirt, pollen or mold.

Other Concerns

Indoor air quality can be adversely impacted by the presence of respiratory irritants, such as products of combustion. The process of combustion produces a number of pollutants; however, the pollutant produced is dependent on the material combusted. Common combustion products include carbon monoxide, carbon dioxide, water vapor and smoke (fine airborne particle material). Of these materials, exposure to carbon monoxide and particulate matter with a diameter of 2.5 micrometers (μm) or less (PM2.5) can produce immediate, acute health effects upon exposure. To determine whether combustion products were present in the school environment, BEHA staff obtained measurements for carbon monoxide and PM2.5. Outdoor carbon monoxide concentrations were non-detect or ND (Table 1). Carbon monoxide levels measured in the school were also ND.

Several air quality standards have been established to address carbon monoxide pollution and prevent symptoms from exposure to these substances. The MDPH established a corrective action level concerning carbon monoxide in ice skating rinks that use fossil-fueled ice resurfacing equipment. If an operator of an indoor ice rink measures a carbon monoxide level over 30 ppm, taken 20 minutes after resurfacing within a rink, that operator must take actions to reduce carbon monoxide levels (MDPH, 1997).

ASHRAE has adopted the National Ambient-Air Quality Standards (NAAQS) as one set of criteria for assessing indoor air quality and monitoring of fresh air introduced by HVAC systems (ASHRAE, 1989). The NAAQS are standards established by the US EPA to protect the public health from 6 criteria pollutants, including carbon monoxide and particulate matter (US EPA, 2000). As recommended by ASHRAE, pollutant levels of fresh air introduced to a building should not exceed the NAAQS (ASHRAE, 1989). The NAAQS were adopted by reference in the Building Officials & Code Administrators (BOCA) National Mechanical Code of 1993 (BOCA, 1993), which is now an HVAC standard included in the Massachusetts State Building Code (SBBRS, 1997). According to the NAAQS established by the US EPA, carbon monoxide levels in outdoor air should not exceed 9 ppm in an eight-hour average (US EPA, 2000).

Carbon monoxide is a by-product of incomplete combustion of organic matter (e.g., gasoline, wood and tobacco). Exposure to carbon monoxide can produce immediate and acute health affects. *Carbon monoxide should not be present in a typical, indoor environment.* If it *is* present, indoor carbon monoxide levels should be less than or equal to outdoor levels.

The NAAQS originally established exposure limits for particulate matter with a diameter of 10 µm or less (PM10). According to the NAAQS, PM10 levels should not exceed 150 micrograms per cubic meter ($\mu g/m^3$) in a 24-hour average. This standard was adopted by both ASHRAE and BOCA. Since the issuance of the ASHRAE standard and BOCA Code, US EPA proposed a more protective standard for fine airborne particles. This more stringent, PM2.5 standard requires outdoor air particulate levels be maintained below 65 $\mu g/m^3$ over a 24-hour average. Although both the ASHRAE standard and BOCA Code adopted the PM10 standard for evaluating air quality, BEHA uses the more protective proposed PM2.5 standard for evaluating airborne particulate matter concentrations in the indoor environment.

Outdoor PM2.5 concentrations were measured at 27 $\mu g/m^3$ (Table 1). PM2.5 levels measured indoors (32 $\mu g/m^3$) were slightly higher than outdoors, they were below the NAAQS of 65 $\mu g/m^3$. Frequently, indoor air levels of particulates (including PM2.5) can be at higher levels than those measured outdoors. A number of mechanical devices and/or activities that occur in schools can generate particulate during normal operations. Sources of indoor airborne particulates may include but are not limited to particles generated during the operation of fan belts in the HVAC system, cooking in the cafeteria stoves and microwave ovens; use of photocopiers, fax machines and computer printing devices; operation of an ordinary vacuum cleaner and heavy foot traffic indoors.

Indoor air quality can also be negatively influenced by the presence of materials containing volatile organic compounds (VOCs). VOCs are carbon-containing substances that have the ability to evaporate at room temperature. Frequently, exposure to low levels of total VOCs (TVOCs) may produce eye, nose, throat and/or respiratory irritation in some sensitive individuals. For example, chemicals evaporating from a paint can stored at room temperature would most likely contain VOCs. In an effort to determine whether VOCs were present in the building, air monitoring for TVOCs was conducted. An outdoor air sample was taken for comparison. Outdoor TVOC concentrations were ND. Indoor TVOC concentrations were also ND (Table 1).

Please note that the TVOC air measurements are only reflective of the indoor air concentrations present at the time of sampling. Indoor air concentrations can be greatly impacted by the use of TVOC containing products. While no TVOC levels measured exceeded background levels, materials containing VOCs were present in the school. The annex contained a dry erase board and dry erase board markers. Materials such as dry erase markers and dry erase board cleaners may contain volatile organic compounds (VOCs) (e.g. methyl isobutyl ketone, n-butyl acetate and butyl-cellusolve) (Sanford, 1999). Dry erase board markers and cleaners can be irritating to the eyes, nose and throat of sensitive individuals.

Conclusions/Recommendations

The conditions noted at the MMES annex raise a number of indoor air quality issues. The combination of poor maintenance of the HVAC system and production of latex dust, if considered individually, present conditions that could degrade indoor air quality. When combined, these conditions can serve to further negatively affect indoor air quality. Some of these conditions can be remedied by actions of building occupants. Other remediation efforts will require alteration to the building structure and equipment. For these reasons a two-phase approach is required, consisting of **short-term** measures to improve air quality and **long-term** measures that will require planning and resources to adequately address the overall indoor air quality concerns.

The following **short-term** measures should be considered for implementation:

1. Examine each univent for function. Survey the univent function to ascertain if an adequate air supply exists. Consider consulting a heating, ventilation and air conditioning (HVAC) engineer concerning the restoration of univent fresh air control dampers throughout the library.
2. Remove all blockages from univents to ensure adequate airflow. Clean interiors of univents regularly.
3. To maximize air exchange, the BEHA recommends that the ventilation system operate continuously during periods of occupancy independent of library thermostat control.
4. Once both the fresh air supply and the exhaust ventilation are functioning, the ventilation system should be balanced.
5. Supplement airflow in library by using openable windows to control for comfort. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.
6. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of

feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

7. Place a plastic mat below the water bubbler. Reduce the water pressure to prevent the wetting of carpeting.
8. In order to maintain a good indoor air quality environment in the building, consideration should be given to adopting the US EPA document, "Tools for Schools", which can be downloaded from the Internet at http://www.epa.gov/iaq/schools/index.html.
9. For further building-wide evaluations and advice on maintaining public buildings, see the resource manual and other related indoor air quality documents located on the MDPH's website at http://www.state.ma.us/dph/beha/iaq/iaqhome.htm.

The following **long-term measures** should be considered:

1. Examine possible methods to properly seal the wall/roof to prevent further wood deterioration.
2. Examine the feasibility of installing a gutter/downspout system on the roof.
3. Water-damaged ceiling tiles should be replaced. These ceiling tiles can be a source of microbial growth and should be removed. Sources of water leaks (e.g. window frames and roof) should be identified and repaired. Examine the non-porous surface beneath the removed ceiling tiles and disinfect with an appropriate antimicrobial.

References

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Picture 1

Items on Unit Ventilator

Picture 2

Subterranean Exhaust Vent Grate

Picture 3

Water Damaged Interlocking Ceiling Tiles

Picture 4

Water Damaged Gypsum Wallboard in Rest Room

Picture 5

Roof Soffit Missing Gutters, Note Breaks in Paint

Picture 6

Former Downspout Drain

Picture 7

Pipe Insulation Inserted into Space between Roof and Exterior Wall

Picture 8

Water Shooting over Bubbler Catch Basin over Carpet

Memorial Elementary School Annex (Library) **Indoor Air Results**

43 Lincoln Street, Manchester MA **March 7, 2004**

Table 1

Location/ Room	Temp (°F)	Relative Humidity (%)	Carbon Dioxide (*ppm)	Carbon Monoxide (*ppm)	TVOCs (*ppm)	PM2.5 (µg/m3)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
Background (outdoors)	67	19	410	ND	ND	27			-	-	Damaged windows-exterior, discolored insulation around AC
Library	69	23	730	ND	ND	32	4	Y	Y univent	Y wall	One window open, temperature complaints, univent deactivated due to excessive heat, exhaust and UV obstructed by furniture and other items, CP, DEM, plants, 4 CT

ppm = parts per million
µg/m3 = micrograms per cubic meter

AD = air deodorizer
AP = air purifier
aqua. = aquarium

AT = ajar ceiling tile
BD = backdraft
CD = chalk dust
CP = ceiling plaster
CT = ceiling tile
DEM = dry erase materials

design = proximity to door
FC = food container
G = gravity
GW = gypsum wallboard
M = mechanical
MT = missing ceiling tile

NC = non-carpeted
ND = non detect
PC = photocopier
PF = personal fan
plug-in = plug-in air freshener
PS = pencil shavings

sci. chem. = science chemicals
TB = tennis balls
terra. = terrarium
UF = upholstered furniture
WP = wall plaster

Comfort Guidelines

Carbon Dioxide: < 600 ppm = preferred
600 - 800 ppm = acceptable
> 800 ppm = indicative of ventilation problems

Temperature: 70 - 78 °F
Relative Humidity: 40 - 60%